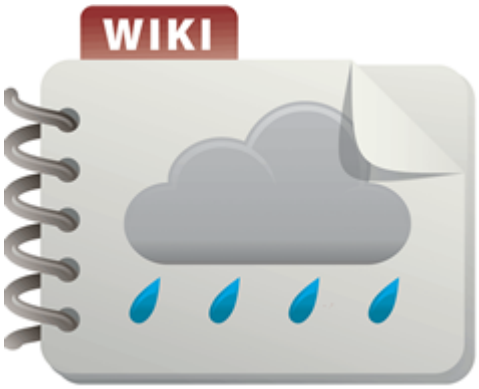

Construction specifications for permeable pavement

Green Infrastructure: Permeable pavement can be an important tool for retention and detention of stormwater runoff. Permeable pavement may provide additional benefits, including reducing the need for de-icing chemicals, and providing a durable and aesthetically pleasing surface.

Proper construction of permeable pavement is critical to its long term performance as a stormwater BMP. Improper or inadequate erosion and sediment control during construction and immediately following construction can cause immediate plugging of the pavement. The construction sequence is also critical to the long term success of the performance of the pavement and is described below. The materials and installation techniques of the three different pavements are very specific and require special attention to detail. Failure to follow the recommendations will likely cause premature structural failure of the pavement or result is pavement without the desired infiltration capacity.

See a video of permeable pavers being installed as part of the Blooming Alleys project. (https://www.youtube.com/watch?v=d7Np09bv3fg)

Contents

Essential erosion and sediment controls

All permeable pavement areas should be fully protected from sediment intrusion by silt fence or construction fencing, particularly if they are intended to infiltrate runoff. They should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Permeable pavement areas should be clearly marked on all construction documents and grading plans. To prevent soil compaction, heavy vehicular traffic should be kept out of permeable pavement areas during and immediately after construction.

During construction, care should be taken to avoid tracking sediments onto any permeable pavement to avoid surface clogging. Any area of the site intended ultimately to be a permeable pavement area should generally not be used as the site of a temporary sediment basin. Where locating a sediment basin on an area intended for permeable pavement is unavoidable, the invert of the sediment basin must be a minimum of one foot above the final design elevation of the bottom of the aggregate reservoir course. All sediment deposits in the excavated area should be carefully removed prior to installing the subbase, base, and surface materials.

Permeable pavement construction sequence

The following is a typical construction sequence to properly install permeable pavement, which may be modified depending on the pavement type.

> **Step 1**. Construction of the permeable pavement begins after the entire contributing drainage area has been stabilized. The proposed site should be checked for existing utilities prior to any excavation.

Caution: Do not install pervious concrete or porous asphalt in rain or snow, and do not install frozen aggregate materials under any of the surfaces

> **Step 2**. Temporary erosion and sediment controls are needed during installation to divert stormwater away from the permeable pavement area until it is constructed and contributing drainage areas have been stabilized by a uniform perennial vegetative cover with a density of at least 70 percent over the entire pervious surface area, or other equivalent means. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during and after the excavation process. The proposed permeable pavement area must be kept free from sediment during the entire construction process.

Caution: Construction materials contaminated by sediments must be removed and replaced with clean materials

> **Step 3**. Where possible, excavation should work from the sides and outside the footprint of the permeable pavement area (to avoid soil compaction). Contractors can utilize a “cell” construction approach, whereby the proposed permeable pavement area is divided into 500 to 1000 square feet temporary cells with 10 to 15 feet wide earthen bridges between them so that the cells can be excavated from the side. Then the earthen bridges are removed. Excavated material should be placed away from the open excavation to maintain stability of the side walls.
>
> **Step 4**. The native soils along the bottom of the permeable pavement system can be scarified or tilled to a depth of 3 to 4 inches and graded prior to the placement of the aggregate.
>
> **Step 5**. Geotextile should be installed on the sides of the reservoir layer applications that do not use concrete curbs extending the full base depth. The design engineer may elect to use geotextile over the soil subgrade as

well. Overlap of each sheet should follow recommendations in AASHTO (http://www.transportation.org/Pages/default.aspx) M-288.

Step 6. Provide a minimum of 2 inches of aggregate around underdrain pipes. The underdrains should slope down towards the outlet at a grade of 0.5 percent or steeper. The up-gradient end of underdrains in the reservoir layer should be capped. Where an underdrain pipe is connected to a structure, there should be no perforations within at least one foot of the structure. Ensure that there are no perforations in clean-outs within at least one foot from the surface.

NOTE: Step 7 (below) previously specified minimum 8 inch lifts. A review of literature suggests this should be maximum lifts of 8 inches, with 4 to 6 inch lifts being preferred. See [1] (http://www.concretenetwork.com/concrete/pavers/installation_overview.html), [2] (http://www.vwrrc.vt.edu/swc/april_22_2010_update/DCR_BMP_Spec_No_7_PERMEABLE_PAVEMENT_Final_Draft_v1-7_03082010.htm), [3] (http://www.wgpaver.com/wp-content/uploads/2012/05/PICP_Base_Construction1.pdf)

Step 7. Spread maximum 8 inch lifts (6 inch preferred) of the reservoir base/subbase or base stone. Moistening the aggregate during spreading will facilitate better compaction. Compact reservoir layers (layer with larger than No. 57 stone) with a 10 ton roller with two passes in static mode or until there is no visible movement of the aggregate. For No. 57 or similar sized stone layers, make two passes in vibratory mode and two passes in static mode or until there is no visible movement of the aggregate. Do not crush the aggregate with the roller. Corners and other areas where rollers cannot reach are compacted with a vibratory plate compactor capable of least 13,500 pound force (lbf) and equipped with a compaction indicator. PICP bases require a 4 inch base layer and this is compacted separately from the subbase layer with two passes in vibratory then two in static mode.

Step 8. Install the desired depth of the bedding or choker layer, depending on the type of pavement, as follows.

- Pervious Concrete: No bedding/choker layer is used.
- Porous Asphalt: The choker layer for porous asphalt pavement consists of 1 inch of washed No. 57 stone.
- PICP: The bedding layer for open-jointed pavement blocks should consist of 2 inches of washed No.8 stone. This layer is compacted after pavers are placed on it and their joints are filled with aggregate.

Step 9. Paving materials should be installed according to manufacturer or industry specifications for the particular type of pavement. Installation highlights are provided below. After the installation is complete, the permeable pavement surface should be tested for acceptance using a minimum infiltration rate of 100 inch/hr using ASTM (http://www.astm.org/) C1701 *Standard Test Method for Infiltration Rate of In Place Pervious Concrete*. This test method can be used on porous asphalt and PICP.

Porous asphalt installation

The following has been excerpted from the Minnesota Asphalt Pavement Association (http://www.asphaltisbest.com/resources_engineering.asp) (MAPA 2012) and from the National Asphalt Pavement Association (http://www.asphaltpavement.org/) (Hansen 2008). These documents should be reviewed for detailed specifications.

- Use PG 58-28 or PG 64-22 asphalt binder.
- Install porous asphalt pavement at according to temperatures recommended in the aforementioned references with a minimum air temperature of 50oF to ensure that the surface does not stiffen before compaction.
- Complete compaction of the surface course when the surface is cool enough to resist a 10-ton roller. One or two passes of the roller are required for proper compaction. More rolling could cause a reduction in the porosity of the pavement.
- The mixing plant must provide certification of the aggregate mix, abrasion loss factor, and asphalt content in the mix.

- Transport the mix to the site in a clean truck with smooth dump beds sprayed with a non-petroleum release agent. The mix should be covered during transportation to control cooling.

Pervious concrete installation

The basic installation sequence for pervious concrete is outlined by the American Concrete Institute in ACI Specification 522.1 (ACI 2010) and can be purchased from the American Concrete Institute (http://www.concrete.org/general/home.asp). Guide specifications for Minnesota applications should be obtained from the Aggregate and Ready Mix Association of Minnesota (http://www.armofmn.com). Concrete installers should successfully complete a recognized pervious concrete installers training program, the Pervious Concrete Contractor Certification Program offered by the National Ready Mix Concrete Association (http://www.nrmca.org/). The basic installation procedure follows:

- Water the underlying aggregate (reservoir layer) before the concrete is placed, so that the aggregate does not draw moisture from the freshly laid pervious concrete.
- After the concrete is placed, approximately 3/8 to 1/2 inch is struck off, using a vibratory screed. This is to allow for compaction of the concrete pavement.
- Compact the pavement with a steel pipe roller. Care should be taken so that over-compaction does not occur.
- Cut joints for the concrete to a depth of ¼ inch.
- Curing: Cover the pavement with plastic sheeting within 20 minutes of the strike-off, and keep it covered for at least seven days. Do not allow traffic on the pavement during this time period.

Installation of interlocking pavers

The basic installation process is described in greater detail by Smith (Smith 2011). Permeable paver job foremen should successfully complete the PICP Installer Technician Course training program offered by the Interlocking Concrete Pavement Institute (ICPI). The ICPI provides a variety of technical courses (http://www.icpi.org/).

The following installation method also applies to clay paving units. Contact manufacturers of composite units for installation specifications. Guide construction specifications are available from the Interlocking Concrete Pavement Institute (http://www.icpi.org/view/documents/search?type=guide_spec&keys=permeable).

- Moisten, place and level the AASHTO No. 2 stone subbase and compact it in minimum 12 inch thick lifts with four passes of a 10-ton steel drum static roller until there is no visible movement. The first two passes are in vibratory mode with the final two passes in static mode. The filter aggregate should be moist to facilitate movement into the reservoir course.
- Place edge restraints before the base layer, bedding and pavers are installed. Permeable interlocking pavement systems require edge restraints to prevent vehicle tires from moving the pavers. Edge restraints may be standard concrete curbs or curb and gutters.
- Moisten, place and level the AASHTO No. 57 base stone in a single lift (4 inches thick). Compact it into the reservoir course beneath with at least four (4) passes of a 10-ton steel drum static roller until there is no visible movement. The first two passes are in vibratory mode, with the final two passes in static mode.
- Place and screed the bedding course material (typically AASHTO No. 8 stone (MnDOT 3127-FA-3), 2 inches thick).
- Pavers may be placed by hand or with mechanical installation equipment.
- Fill gaps at the edge of the paved areas with cut pavers or edge units. When cut pavers are needed, cut the pavers with a paver splitter or masonry saw. Cut pavers no smaller than one-third (1/3) of the full unit size if subject to tires.
- Fill the joints and openings with stone. Joint openings must be filled with AASHTO No. 8 (MnDOT 3127-FA-3), 89 or 9 (MnDOT 3127 FA-2)stone per the paver manufacturer’s recommendation. Sweep and remove excess stones from the paver surface.

- Compact and seat the pavers into the bedding course with a minimum low-amplitude 5,000 lbf, 75- to 95 Hz plate compactor. Do not compact within 6 feet of the unrestrained edges of the pavers.
- Thoroughly sweep the surface after construction to remove all excess aggregate.
- Inspect the area for settlement. Any paving units that settle must be reset and inspected.
- The contractor should return to the site within 6 months to top up the paver joints with stones.

Construction inspection

Inspections before, during and after construction are needed to ensure that permeable pavement is built in accordance with these specifications. Use a detailed inspection checklist that requires sign-offs by qualified individuals at critical stages of construction and to ensure that the contractor's interpretation of the plan is consistent with the designer's intent. The following checklist provides an example.

Pre-construction meeting

- Walk through site with builder/contractor/subcontractor to review erosion and sediment control plan/stormwater pollution prevention plan (SWPPP)
- Determine when permeable pavement is built in project construction sequence; before or after building construction and determine measures for protection and surface cleaning
- Aggregate material locations identified (hard surface or on geotextile)

Sediment management

- Access routes for delivery and construction vehicles identified
- Vehicle tire/track washing station location/maintenance (if specified in the erosion and sediment control plan (SWPPP))
- Ensure that the contributing drainage areas are stabilized and are not eroding

Excavation

- Utilities should be located and marked by local service provider
- The excavated area should be marked with paint and/or stakes
- The excavation size and location should conform to the plan
- Excavation hole as sediment trap: The hole cleaned should be cleaned immediately before subbase stone placement and runoff sources with sediment diverted away from the pavement or all runoff diverted away from the excavated area.
- Temporary soil stockpiles should be protected from run-on, run-off from adjacent areas and from erosion by wind.
- Ensure linear sediment barriers (if used) are properly installed, free of accumulated litter, and built up sediment less than 1/3 the height of the barrier.
- No runoff should enter the pavement until soils are stabilized in the area draining to the pavement
- Foundation walls should be waterproofed
- Soil subgrade: rocks and roots removed, voids should be refilled with base aggregate
- Soil should be compacted to specifications (if required) and field tested with density measurements per specifications
- No groundwater seepage or standing water. If groundwater seepage is present, dewatering and possibly a dewatering permit may be required.

Geotextiles

- Must meet the design specifications
- Sides of excavation should be covered with geotextile prior to placing aggregate base/subbase
- Placement and down slope overlap (minimum of 2 feet) should conform to specifications and drawings

- No tears or holes should be present
- No wrinkles should be present and the fabric should be pulled taught and staked

Impermeable liners (if specified; see here (http://stormwater.pca.state.mn.us/index.php/Liners_for_stormwater_management))

- Must meet the specifications
- Placement, field welding, and seals at pipe penetrations should be completed per the design specifications

Drain pipes/observation wells

- Size, perforations, locations, slope, and outfalls must meet specifications and drawings
- Verify the elevation of overflow pipes
- Underdrains should be capped at upslope ends

Aggregates

- Test results should conform to specifications
- Aggregates should be spread (not dumped) with a front-end loader to avoid aggregate segregation
- Storage on hard surface or on geotextile to keep sediment-free
- Thickness, placement, compaction and surface tolerances should meet specifications and drawings

Once the final construction inspection has been completed, log the GPS coordinates for each facility and submit them for entry into the local BMP maintenance tracking database.

Construction inspection checklists

Construction inspection checklists have not been developed for the Minnesota Stormwater Manual. We anticipate developing these in 2018. Below are links to checklists developed by other organizations.

- Fairfax County, 3rd Party Construction Inspection Checklist and Certification: Permeable Pavement (https://www.fairfaxcounty.gov/publicworks/sites/publicworks/files/assets/documents/pdf/publications/spec-7-permeable-pavement.pdf)
- Prince George's County, Permeable Pavement Construction Inspection Checklist (https://www.princegeorgescountymd.gov/DocumentCenter/View/11099)

Minnesota Department of Transportation example construction protocols

Preliminary analysis and selection

Recommended number of soil borings, pits or permeameter tests for bioretention design. Designers select one of these methods.
Link to this table

Surface area of stormwater control measure (BMP)(ft^2)	Borings	Pits	Permeameter tests
< 1000	1	1	5
1000 to 5000	2	2	10
5000 to 10000	3	3	15
>10000	4[1]	4[1]	20[2]

[1]an additional soil boring or pit should be completed for each additional 2,500 ft^2 above 12,500 ft^2

[2]an additional five permeameter tests should be completed for each additional 5,000 ft^2 above 15,000 ft^2

Field verification testing prior to pond construction

- Soil hydraulic group represent what is stated in SWPPP (Stormwater Pollution Prevention Plan)
- Seasonally high water table not discovered within 3 feet of the excavated pond base within a test pit
- Commonly will test bottom of proposed pond for soil compaction (subsequent subsoil ripping) prior to media placement
- Commonly will test bottom of proposed pond for insitu infiltration rate by test pit or water filled barrel placed on pond base surface

Filter media and material testing

- Existing soil (option 1 below) or Washed sand (option 2 below), and compost certification
- Washed course aggregate choker certification
- Other treatment material certification of iron filings, activated charcoal, pH buffers, minerals, etc.
- Geotextile separation fabric certification
- Drain-tile certification (if filtration is specified)
- Seed source certification
- Barrel test verification of infiltration rate using 2.5 feet of imported 3877 Type G media (https://www.dot.state.mn.us/pre-letting/spec/2018/2018-spec-book-final.pdf)

Field verification testing/inspection/verification during construction

- Water drains away in 48 hours
- Infiltration drainage rate does not exceed 8.3 inches per hour
- No tracking/equipment in pond bottom
- No sediment deposits from ongoing construction activity, media perimeter controls kept functional
- Forebay is trapping settleable solids, floating materials, and oil/grease
- Area staked off

Notice of Termination (NOT) verification

- **Option 1. Amending existing HSG soils with compost or other treatment material.** Test the infiltration rate of each infiltration basin using a double ring infiltrometer prior to completion of the basin. Conduct the test at the finished grade of the basin bottom, prior to blending the compost with the in-situ soils or sand. Ensure infiltration rates meet or exceed greater of two times the designed infiltration rate or 2 inches per hour. Conduct a minimum of five tests per representative acre of basin area and a minimum of five tests per basin. Conduct double ring infiltrometer tests in accordance with ASTM standards. Thoroughly wet test areas prior to conducting infiltrometer tests.
- **Option 2. Importing 3877 Type G Filter Topsoil Borrow (may be amended with other treatment material)**. Ensure infiltration rates meet or exceed greater of two times the designed infiltration rate or 2 inches per hour, or rate specified in the plan. Conduct a minimum of five tests per representative acre of basin area and a minimum of five tests per basin. Conduct double ring infiltrometer tests in accordance with ASTM standards. Thoroughly wet test areas prior to conducting infiltrometer tests. Amend soils with additional washed sand if rates less than specified in the contract, or compost if rates exceed 8.3 inches per hour.

The permanent stormwater management system must meet all requirements in sections 15, 16, and 17 of the CSW permit (https://stormwater.pca.state.mn.us/index.php?title=2018_Minnesota_Construction_Stormwater_Permit) and must operate as designed. Temporary or permanent sedimentation basins that are to be used as permanent water quality management basins have been cleaned of any accumulated sediment. All sediment has been removed from conveyance systems and ditches are stabilized with permanent cover.

Related articles

- Overview for permeable pavement
- Types of permeable pavement
- Design criteria for permeable pavement
- Construction specifications for permeable pavement
- Assessing the performance of permeable pavement
- Operation and maintenance of permeable pavement
- Calculating credits for permeable pavement
- Case studies for permeable pavement
- Green Infrastructure benefits of permeable pavement
- Summary of permit requirements for infiltration
- Permeable pavement photo gallery
- Additional considerations for permeable pavement
- Links for permeable pavement
- References for permeable pavement
- Fact sheets for permeable pavement
- Requirements, recommendations and information for using permeable pavement BMPs in the MIDS calculator

Permeable pavement main page (https://stormwater.pca.state.mn.us/index.php?title=Permeable_pavement)